Calorimetry

V Vijaykiran
M.Sc., B.Ed., NET
SIGMA Physics Resource Centre
http://www.sigmaprc.in

Heat

- Heat is a form of energy in transit
- Flow of heat takes place from a region of higher temperature to a region of lower temperature
- SI unit of heat energy is joule (J)

Heat is required to raise the temperature of a body.
The amount of heat required depends on
(a) nature of the material
(b) quantity of the substance
(c) temperature difference through which it is to be heated.

Heat and Temperature

Heat is a form of energy in transit.

It SI unit is joule.

Heat is a derived quantity

Temperature is a measure of hotness or coldness of a body.

SI unit of temperature is kelvin (K)

Temperature is a fundamental quantity

The amount of heat flow from one body to another depends on the temperature difference between the bodies.

Specific heat

Amount of heat to be supplied depends on

- mass of the body $\mathrm{d}Q \propto m$
- change in temperature of the body $\mathrm{d}Q \propto \mathrm{d}T$

$$\boxed{\mathrm{d}Q = s\, m\, \mathrm{d}T}$$

The constant of proportionality is called specific heat (s) .

Specific heat is defined as the amount of heat required to raise the temperature of a unit mass of a substance by unity.

SI unit of s is J kg^{-1} K^{-1}

Its value depends on the nature of the material.

If the amount of substance is given in moles (n) then the relation is

$$\boxed{\mathrm{d}Q = C\, n\, \mathrm{d}T}$$

C is called molar specific heat. It is defined as the amount of heat required to raise the temperature of a unit mass of a substance by unity.

Heat capacity

It is the amount of heat required to raise the temperature of the given body by unity.

$$\mathrm{d}Q = m\,s\,\mathrm{d}T$$

$$m\,s = \frac{\mathrm{d}Q}{\mathrm{d}T}$$

(ms is called heat capacity)

Water equivalent

The amount (mass) of water that undergoes the same change in temperature as the given body is called water equivalent of the body.

Heat capacity, specific heat capacity and molar specific heat capacity are defined only for the situation where the substance does not undergo any change in its state

Latent heat

It is the amount of heat required to cause a change in the state of a body at constant temperature.

$$\boxed{Q = m L}$$

Latent heat of vaporization

- It is the amount of heat required to cause a change from liquid state to the vapour state for a unit mass of a material , at constant temperature.
- It is the amount of heat liberated when unit mass of a vapour converts to liquid
- SI unit of latent heat of vaporization is Jkg^{-1}

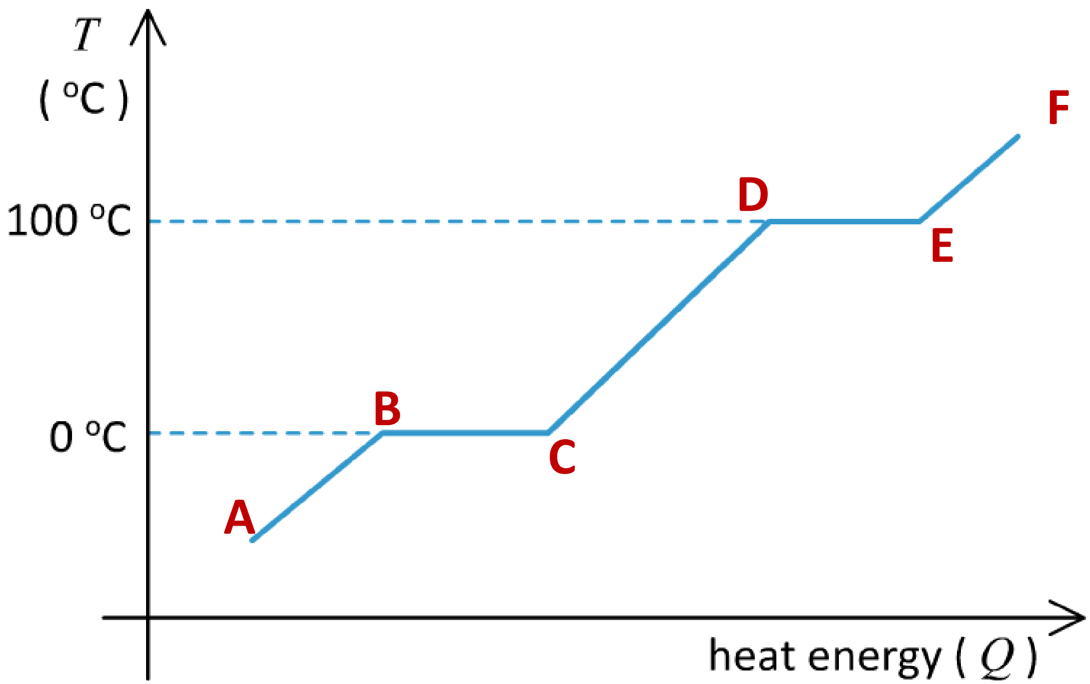
Latent heat of fusion

- It is the amount of heat required to cause a change from solid state to liquid state for a unit mass of a material , at constant temperature.
- It is the amount of heat liberated by unit mass of a liquid as it converts to solid
- SI unit of latent heat of fusion is Jkg^{-1}

Latent heat is defined only for the situation where the substance undergoes change in its state at constant temperature

Temperature of a sample of water when heat is supplied to it at a constant rate

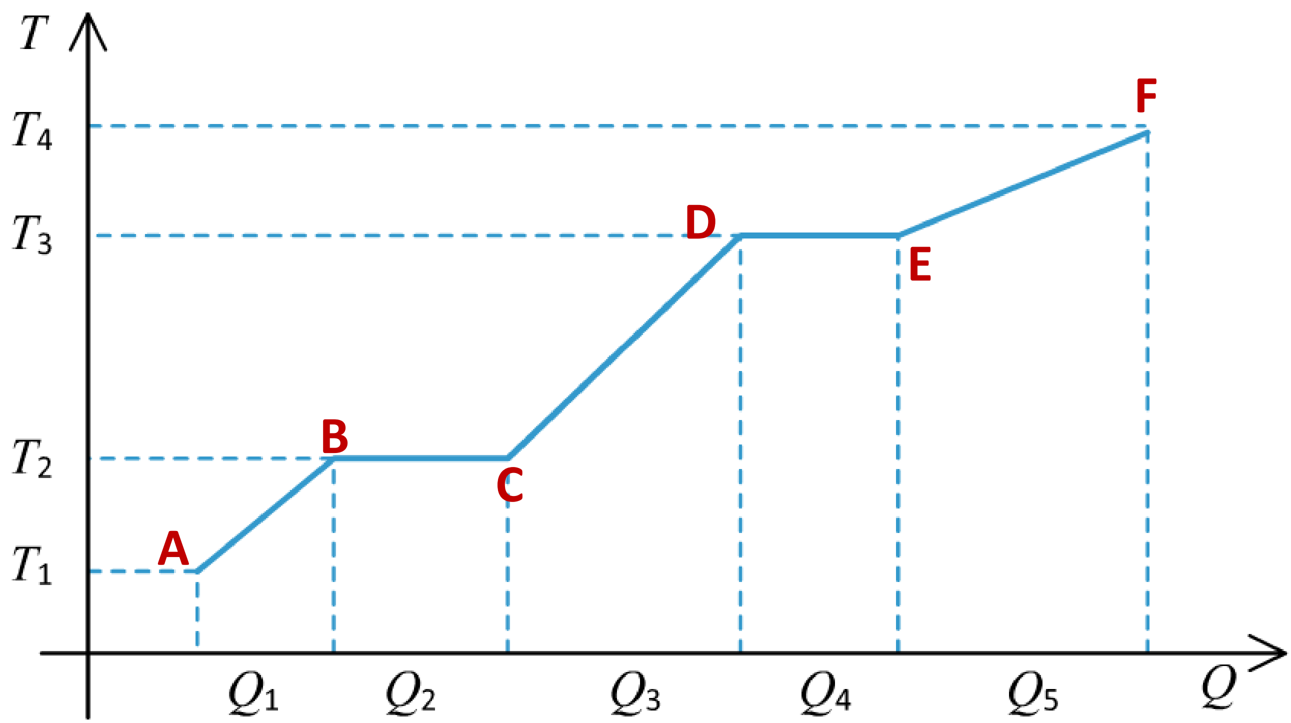
Consider a unit mass of ice at a sub-zero temperature. Let heat be supplied to it uniformly at a constant rate resulting in a change in its temperature and a change in the state of the substance.



- **A to B**
  Change in temperature in solid state (ice)
- **B to C**
  Change of state from solid to liquid at 0°C
- **C to D**
  Change in temperature in liquid state
- **D to E**
  Change of state from liquid to gas at 100°C
- **E to F**
  Change in temperature in gaseous state

Total heat energy required in a multi-step process

Consider a certain mass (m) of a substance at a sub-zero temperature. Heat required to convert it to vapour at a certain final temperature is as given below



- **A to B**

$$Q_1 = m\, s_1 (T_2 - T_1)$$

- **B to C**

$$Q_2 = m\, L_{\text{fusion}}$$

- **C to D**

$$Q_3 = m\, s_2 (T_3 - T_2)$$

- **D to E**

$$Q_4 = m\, L_{\text{vaporization}}$$

- **E to F**

$$Q_5 = m\, s_3\, (T_4 - T_3)$$

$$\boxed{Q_{\text{total}} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5}$$

Principle of calorimetry (method of mixtures)

- Calorimetry means measurement of heat
- A device that is used for the measurement of heat is called as calorimeter
- When two bodies at different temperatures are brought in thermal contact with each other, then there is a heat exchange between the bodies.
- For an isolated system consisting of two bodies, heat given out by one body is equal to the heat lost by the other body.

$$\boxed{\Delta Q_1 + \Delta Q_2 = 0}$$

Skating

Skating is possible on snow because high pressure under the skates causes the ice to melt. Water which is formed acts as a lubricant and facilitates skating.

Thermal properties of matter

S_{ice}	=	2.093×10^3 J Kg $^{-1}$K^{-1}	=	0.5 cal g^{-1} K^{-1}
S_{water}	=	4.186×10^3 J Kg $^{-1}$K^{-1}	=	1.0 cal g^{-1} K^{-1}
S_{steam}	=	1.97×10^3 J Kg $^{-1}$K^{-1}	=	0.48 cal g^{-1} K^{-1}
$L_{\text{fusion of ice}}$	=	3.36×10^5 J kg^{-1}	=	80 cal g^{-1}
$L_{\text{vap of water}}$	=	2.26×10^6 J kg^{-1}	=	540 cal g^{-1}

- <u>Water equivalent</u>
  It is the amount of water that has the same heat capacity as that of a given body
- Mechanical equivalent of heat (J) = 4.2 J cal^{-1}
- Universal gas constant (R) = 8.312 J mol^{-1}K^{-1}

$$\frac{X\ \text{- LFP}}{\text{UFP - LFP}} = \text{constant}$$

$$\boxed{\frac{C}{5} = \frac{F-32}{9}}$$

$$\boxed{T = T_C + 273.15}$$

$$\boxed{\mathrm{d}Q = s\,m\,\mathrm{d}T}$$

$$\boxed{\mathrm{d}Q = C\,n\,\mathrm{d}T}$$

$$\boxed{Q_{\text{total}} = Q_1 + Q_2 + Q_3 + Q_4 + Q_5}$$

$$\boxed{\Delta Q_1 + \Delta Q_2 = 0}$$

sigmaprc@gmail.com
sigmaprc.in